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Flash Memory Operates 10-20 Times Longer

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Major technology changes in the 1990's will place new demands on memory devices. Mainframe computing performance is now available in a laptop PC, and hand-held solid-state calculators have become sophisticated organizers. The convergence of these two trends has led to the evolution of the notebook PC and the emergence of Flash memory.

With a minimum battery life of 20 hours and weight not exceeding five lbs, the completely solid-state notebook PC will reliably handle all performance requirements of the traveler. Flash memory helps make the design goals of the notebook computer a reality by replacing the majority of the memory technologies in the system. Psion, a leader in the notebook computer market, has created a product in which Flash memory is used for BIOS, OS, and secondary storage. This completely solid-state, DOS-compatible machine weighs only 4.5 lbs and operates on eight AA batteries for 25 hours.

To incorporate rapidly improving power management techniques for battery-powered systems, the BIOS must be software updatable—remotely over a modem or with a floppy disk sent by the OEM. As such, the EPROM no longer fulfills its classic role for code storage. However, designed with a similar memory cell structure based on ETOX technology (EPROM Tunnel Oxide), Intel Flash memory provides equivalent reliability and nonvolatility with the added advantage of one sec, chip-level, electrical erasability (hence the name 'flash'). Flash memory can occupy the EPROM's socket with minor hardware modifications, primarily, 12V (Vpp) and write enable (W/E) must be supplied to enable the software controlled erase and program operations.

Traditionally, when the computer boots up, the operating system (namely DOS) is read from the disk and downloaded to DRAM. Digital Research and Microsoft offer ROM-executable versions of DOS. Originally designed for the unchangeable ROM, this product now accommodates Flash memory which can easily be reloaded with newer revisions without removal from the system. Flash-executable DOS benefits the notebook computer because it reduces the system RAM required for DOS from 70K to 15K, reflecting both power and component savings. Additionally, the system bootup is almost instantaneous, commonly referred to as 'instant-on.'

Solid State Secondary Storage

Solid-state secondary storage has had the greatest overall impact on the notebook computer (See Fig). In this environment, the power consumption, reliability, size, and weight of the mechanical disk drive is unacceptable. For example, the active and standby modes of the small form factor (2 1/2-in.), 20 Mbyte disk drive typically consume 4W and 0.5W, respectively. As a comparison, the active and standby modes of the equivalent capacity of Flash memory, consisting of low power CMOS circuitry, typically consume only 0.15W and 0.04W, respectively. Obviously, for a truly accurate analysis, other components of the system should be included, but from the data storage point of view alone, the Flash memory disk will operate 10-20 times longer than the mechanical disk on a set of batteries.

Reliability issues will always exist with mechanical media in any type of portable equipment because of shock and vibration, but it is difficult to perform a theoretical analysis on this subject. Suffice it to say, that from an MTBF standpoint (as measured by disk drive manufacturers under normal operating conditions), a mechanical disk will typically run 50,000 hours. A Flash memory device (capable of 100,000 erase/program cycles) should continue to function past 1.6 million hours—a difference of two

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Flash Memory Should Offer 1.6 Million Hr MTBF

orders of magnitude.

Size and weight are also critical factors in the notebook computer. Two Mbits of Flash memory is now available in a thin small outline package (TSOP) with a height of 1.2 mm. Minimally, 16 of these tiny packages can be put into a pocket-sized IC memory card (15,789 cm^3 vs 215,384 cm^3 for the 2 1/2-in. mechanical disk drive) to make up a four Mbyte disk, an adequate supply of memory for the notebook computer. Flash memory is not the only technology used as a solid-state alternative to secondary storage. ROM and battery-backed SRAM drives are actually more common because of familiarity. However, each has inherent drawbacks. ROMs have historically been used in laptop systems to store unchangeable, preloaded software programs. To upgrade with software revisions, the ROM application hardfile is discarded and a new card is purchased—an undesirable expense for the user.

Battery-backed SRAMs enable the flexibility to continuously modify files. SRAMs are used both as floppy and hard drive replacements, only where very low densities are required. Besides not being practical for high-density applications, SRAMs also draw concern from unpredictable battery life.

Unlike the ROM drive, flash memories can be reprogrammed many times. Unlike SRAMs, the single transistor memory cell of flash (compared to 4-6 transistors for SRAM) is very scalable for photolithographic processes, promoting very high density devices. In an environment where high density is synonymous with secondary storage, flash will outsell and outlast volatile SRAMs because of cost and reliability advantages.

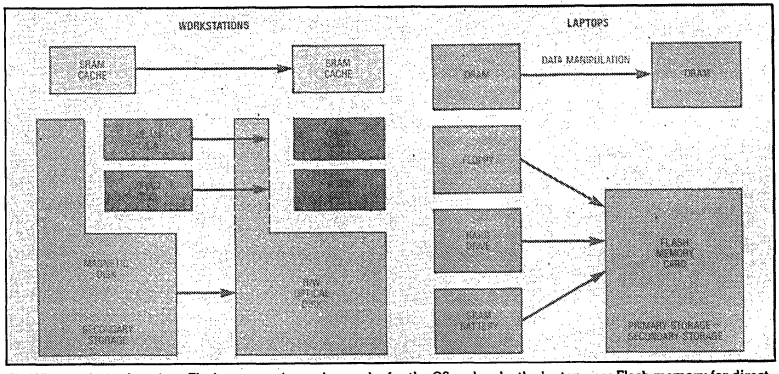

Fig Whereas in workstations Flash memory is used as cache for the OS and code, the laptop uses Flash memory for direct execution.

Using Flash memory

The adoption of Flash memory in a solid-state disk comes with the design challenge of interfacing a bulk-erasable memory with a file system requiring byte-level alterability. The simplest solution is to use a ROM-like approach and use the drive as an application hardfile with the extra benefit of being able to erase and reuse the disk. Microsoft has made major advances over this approach by developing a special file system it calls Flash File System. Based on linked-list techniques, this DOS-compatible file system, with superior performance over the mechanical disk, takes advantage of the chip-level erasability of Flash memory.

Although we have only discussed Flash memory applications in the notebook computer, its usage spreads well beyond. BIOS modification in desktop computers is also unavoidable due to increasing system complexity. Primarily aimed at fixing bugs, this technique also alleviates compatibility problems that might arise from the installation of the myriad of add-in boards and software packages. In addition, the OEM can promote upgrade service as a market distinction, as done by NCR and Olivetti.

Flash memory disks are useful as application caches in high-end systems because of their nonvolatility and RAM-disk equivalent access speeds. Many types of industrial equipment are using Flash memory for code storage and data accumulation, replacing all forms of disk drives, both mechanical and solid-state.

Flash memory will continue to play a dominant role in the evolution of the notebook computer as well as every other application requiring a nonvolatile, reprogrammable, reliable, high density, and low cost memory. The flexibility of this new memory technology is driving costs down and generating an important alternative to disk memory. ■

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